Coherent Deuteron Scattering

(g10 Data)

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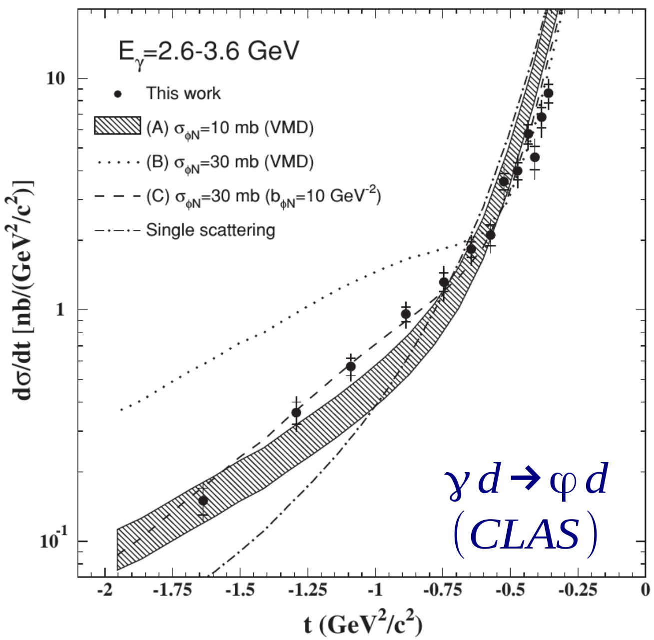
OUTLINE

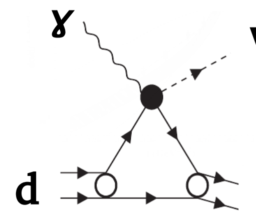
- Motivation
- PID Spectra
- Basic Cuts
- γ d → ρd → $\pi^+\pi^- d$
  - Global Spectrum
  - Acceptance
  - Yield Extraction
  - Preliminary Results
- γ d → ωd → $\pi^+\pi^- d$ (π^0)
  - Global Spectrum
  - Acceptance
  - Yield Extraction
  - Preliminary Results
- γ d → πd* → $\pi^+\pi^- d$
  - Global Spectra
  - Acceptance
  - Yield Extraction
  - VERY Preliminary Results
- Conclusion

MOTIVATION

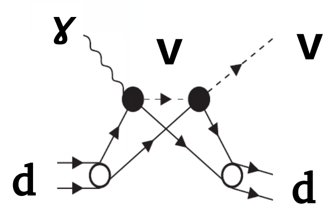


T. Mibe *et al.* **PRC 76, 052202(R)** (2007)

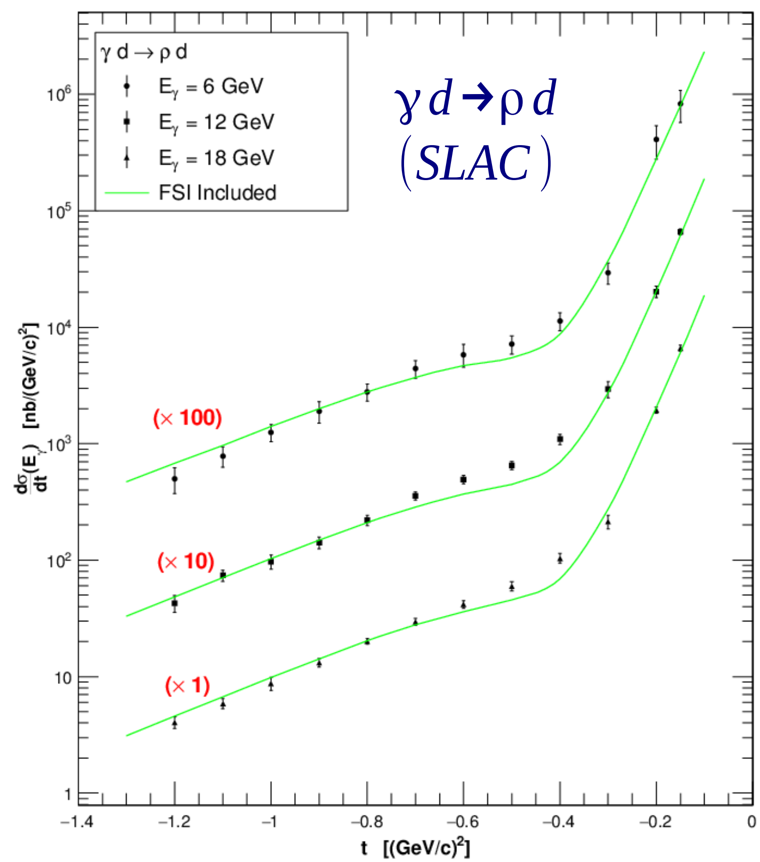
Single scattering



Double scattering



Differential Cross Section of γ d → ρ d (SLAC)



I. D. Overman *et. al.* **SLAC-140, UC-34** (1971)

- Vector Meson beams cannot be produced in a lab.
- These studies will allow to test models of hadronic scattering of ρ and ω-mesons from the nucleon.
- Limited world data for these channels.

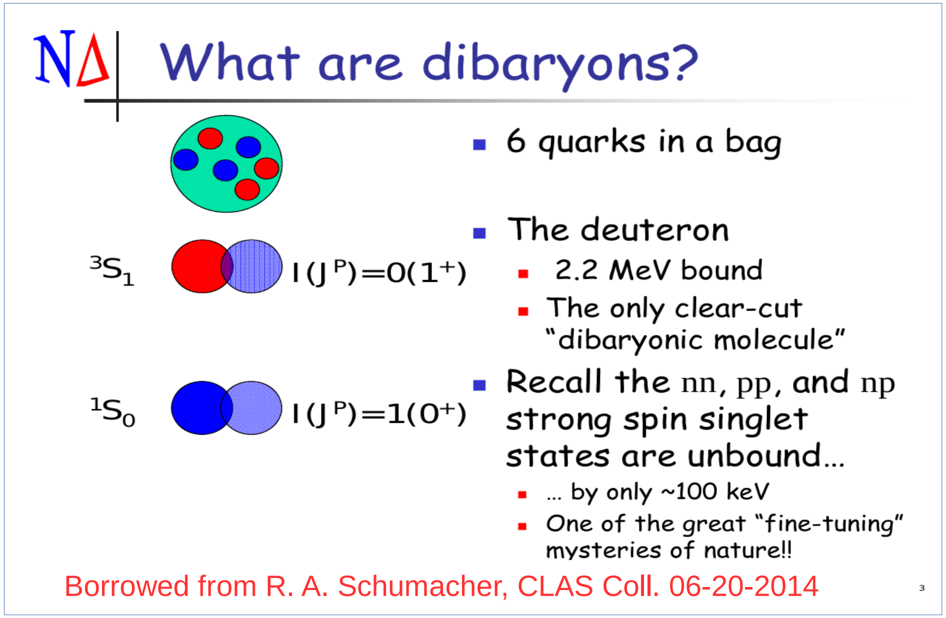
Mandelstam *t* :

$$t = (P_\gamma - P_V)^2 = (P_{d_i} - P_{d_o})^2$$

Reactions in interest

$$\gamma d \to \rho d \qquad \gamma d \to \omega d$$

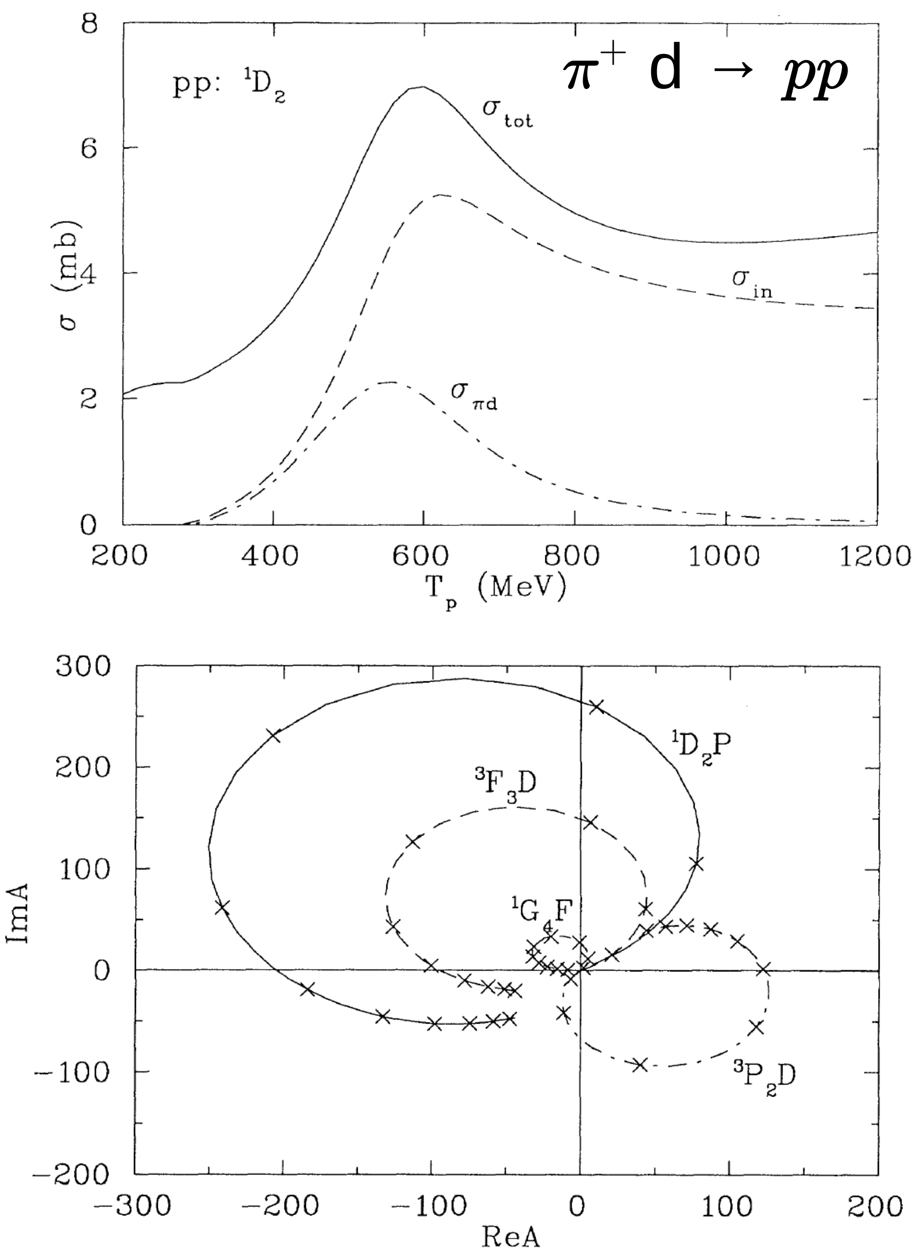
DIBARYON



- Theoretically expected and long sought resonances.

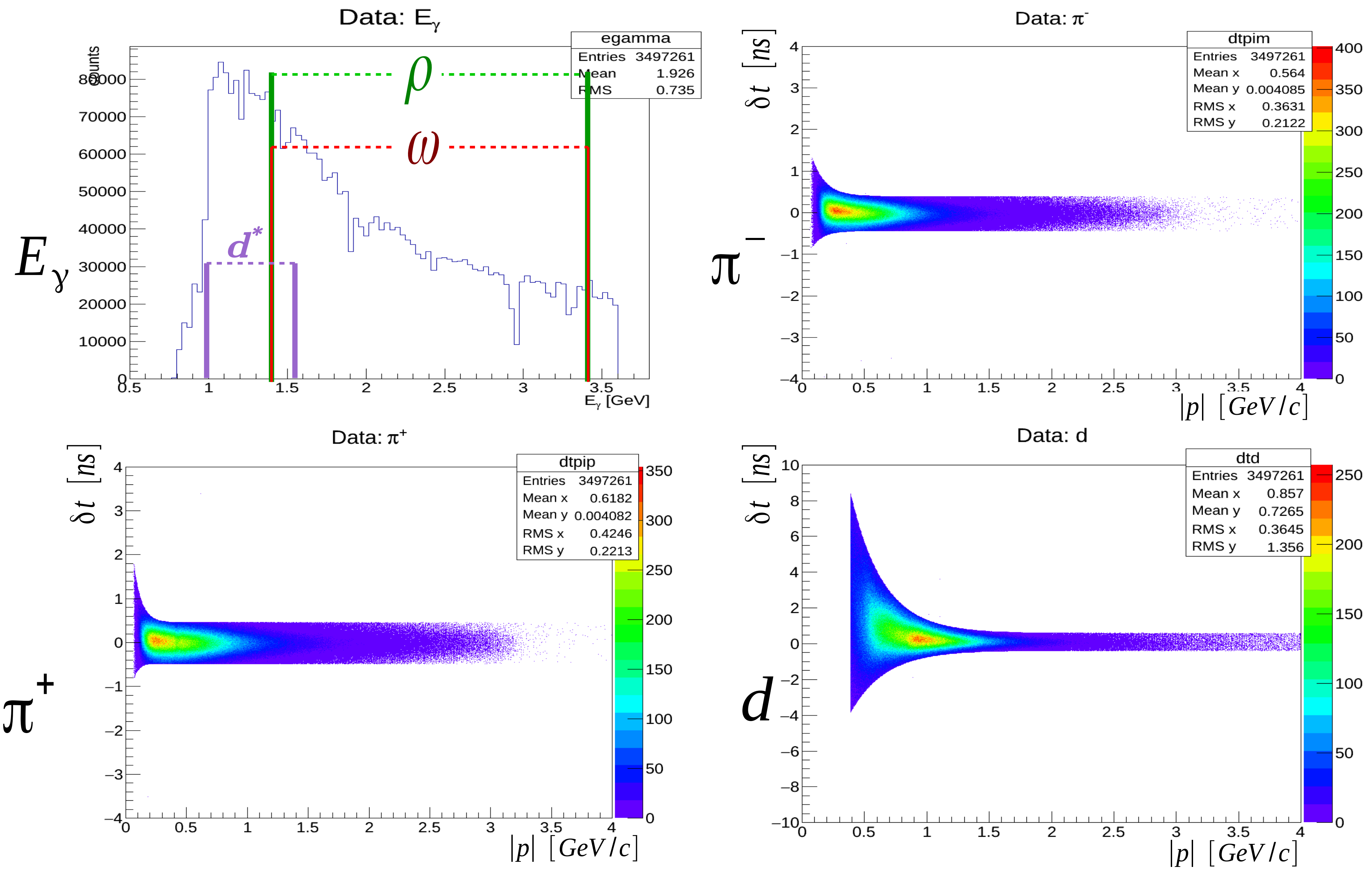
- d* (2145): Partial Wave Analysis
  - Arndt *et al*. **Phys. Rev. C 48, 1926 (1993)**

- Recently claimed d* (2380).
  $pn \rightarrow d\pi^0\pi^0$



Arndt *et al*. **Phys. Rev. C 48, 1926 (1993)**

PID (Data)



Data: E_γ
egamma
Entries 3497261
Mean 1.926
RMS 0.735
Counts
E_γ [GeV]
ρ
ω
d^*
E_γ
Data: π^-
dtpim
Entries 3497261
Mean x 0.564
Mean y 0.004085
RMS x 0.3631
RMS y 0.2122
δt [ns]
$|p|$ [GeV/c]
π^-
Data: π^+
dtpip
Entries 3497261
Mean x 0.6182
Mean y 0.004082
RMS x 0.4246
RMS y 0.2213
δt [ns]
$|p|$ [GeV/c]
π^+
Data: d
dtd
Entries 3497261
Mean x 0.857
Mean y 0.7265
RMS x 0.3645
RMS y 1.356
δt [ns]
$|p|$ [GeV/c]
d

BASIC CUTS

- Timing cuts made using momentum-dependent analysis

- -40 cm < z_{vertex} < -10 cm

- Fiducial cuts applied:
  - $\phi = ae^{b\theta}c + c$
  - Theta cut: $\theta_{\pi\text{-},d} > 0.1\ [rad]$; $\theta_{\pi+} > 0.25\ [rad]$;
  - Bad scintillator paddles removed.

Particle	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6
π^+	23, 27 ≥ 43	≥ 45	11, 23, 31 ≥ 40	23, 33, 35 ≥ 46	23, 29 ≥ 46	23 ≥ 45
π^-	23, 27 ≥ 41	≥ 41	11, 15, 16, 23, 34-36, ≥ 41	23, 27, 35 ≥ 43	20, 23, 29 ≥ 43	23 ≥ 42
d	23, 27 ≥ 35	23 ≥ 35	11, 22, 23 ≥ 35	23 ≥ 35	23 ≥ 35	23 ≥ 35

BASIC CUTS

- MM^2 cut

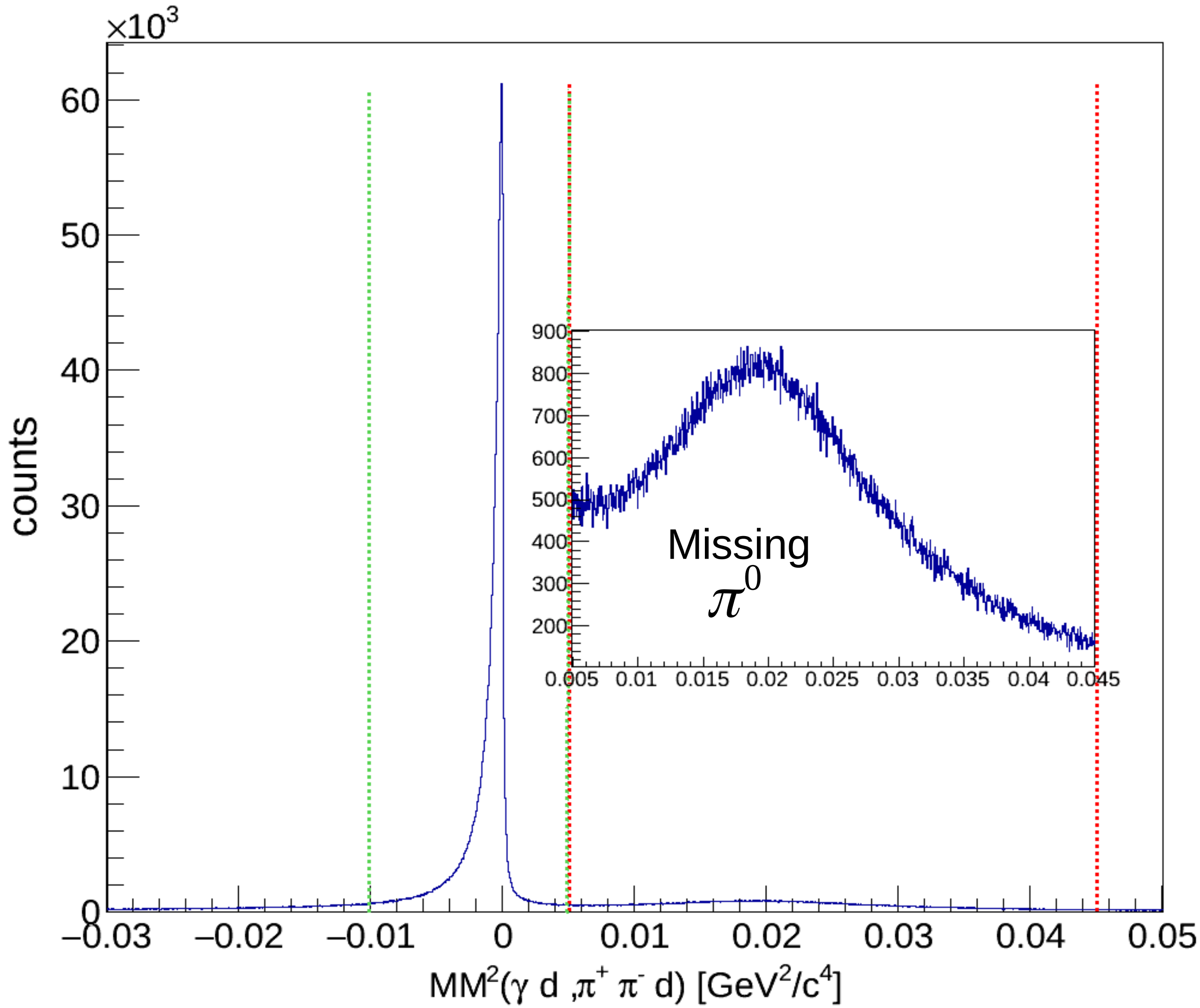
γ d → ρd → $\pi^+\pi^- d$

γ d → πd* → $\pi^+\pi^- d$

$-0.01 < MM^2 < 0.005 \quad [GeV^2/c^4]$

γ d → ωd → $\pi^+\pi^- d$ (π^0)

$0.005 < MM^2 < 0.045 \quad [GeV^2/c^4]$



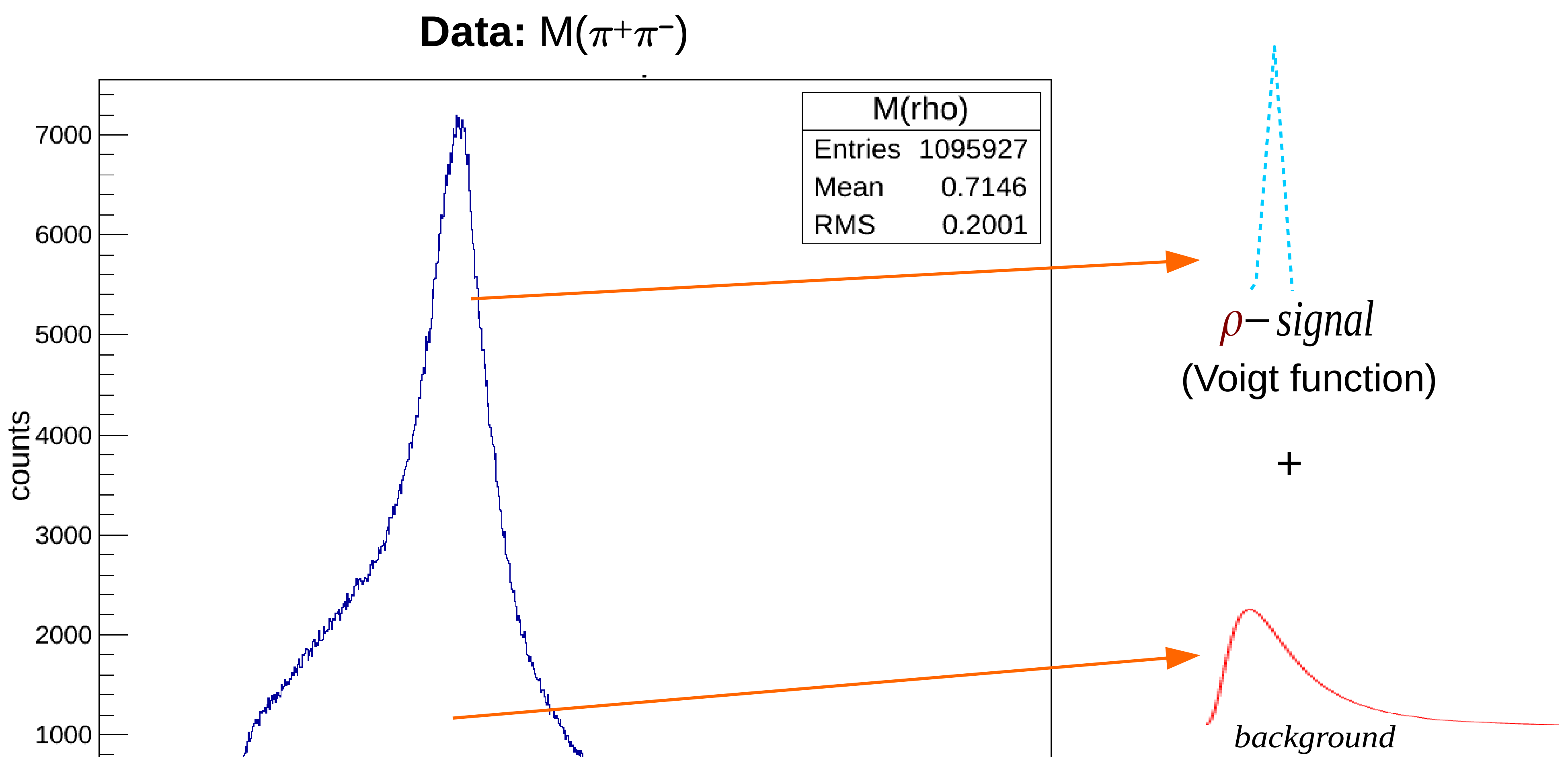
$$\gamma\ \mathrm{d} \rightarrow \rho \mathrm{d} \rightarrow \pi^{+}\pi^{-} d$$

$$\gamma\ \mathrm{d} \rightarrow \omega \mathrm{d} \rightarrow \pi^{+}\pi^{-} d\ (\ \pi^{0})$$

$$\gamma\ \mathrm{d} \rightarrow \pi \mathrm{d}^{*} \rightarrow \pi^{+}\pi^{-} d$$

GLOBAL SPECTRUM

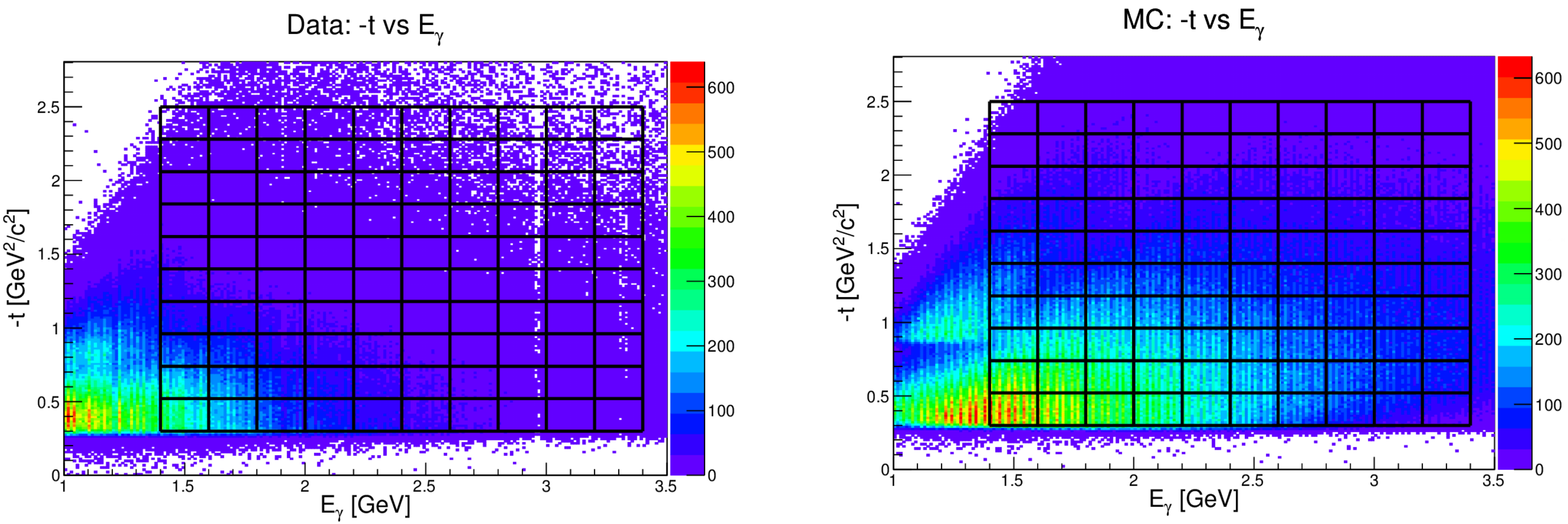
$\gamma\, d \rightarrow \rho d \rightarrow \pi^{+}\pi^{-}d$



$$f_{bckg}(x) = \frac{[b(x+c)]^{a}}{e^{a/[b(x+c)]} - 1}$$

$$f_{bckg}(x) = a + bx + cx^{2} + dx^{3}$$

BINNING

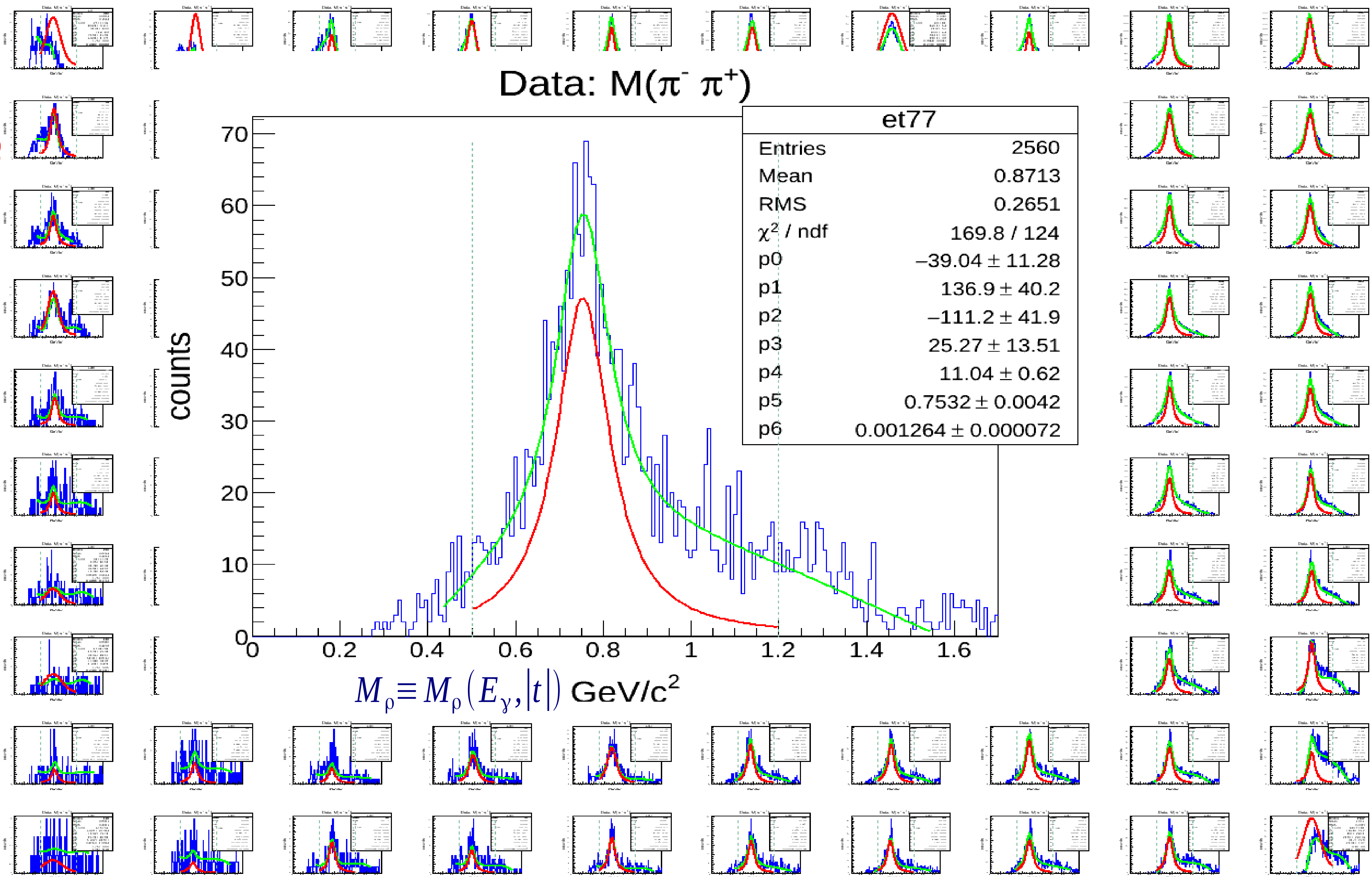


- Data and MC events binned in 10 incident photon energy and 10 4-momentum transfer bins.
- $$1.4 < E_\gamma < 3.4\ [GeV]$$
  $$-2.5 < t < -0.3\ [GeV^2/c^2]$$

YIELD EXTRACTION

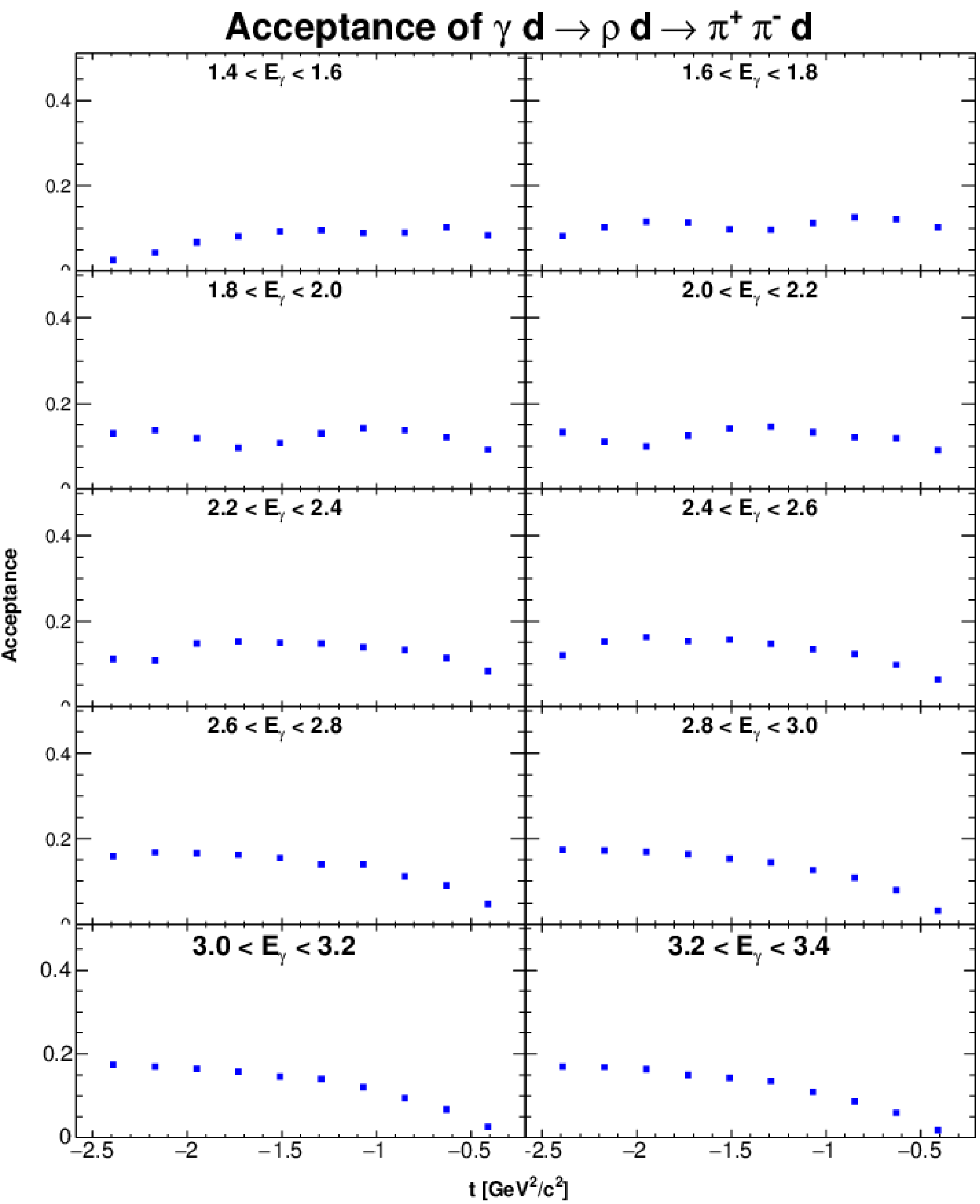
$\gamma\, d \rightarrow \rho d \rightarrow \pi^{+}\pi^{-} d$

E-bins



|t|-bins

ACCEPTANCE & WORKING FORMULA



Differential Cross Section:

$$\frac{d\sigma}{dt}(E_\gamma) = \frac{Yield}{(\delta t)\, A\, L(E_\gamma)} \;;$$

$A \equiv Detector\ Acceptance$

Luminosity,

$$L = \frac{\rho_d N_A l_d}{M_d} N_\gamma$$

$N_\gamma \equiv N_\gamma(E_\gamma)$

$\rho_d = 0.169\, g\ cm^{-3}$

$l_d = 24\, cm$

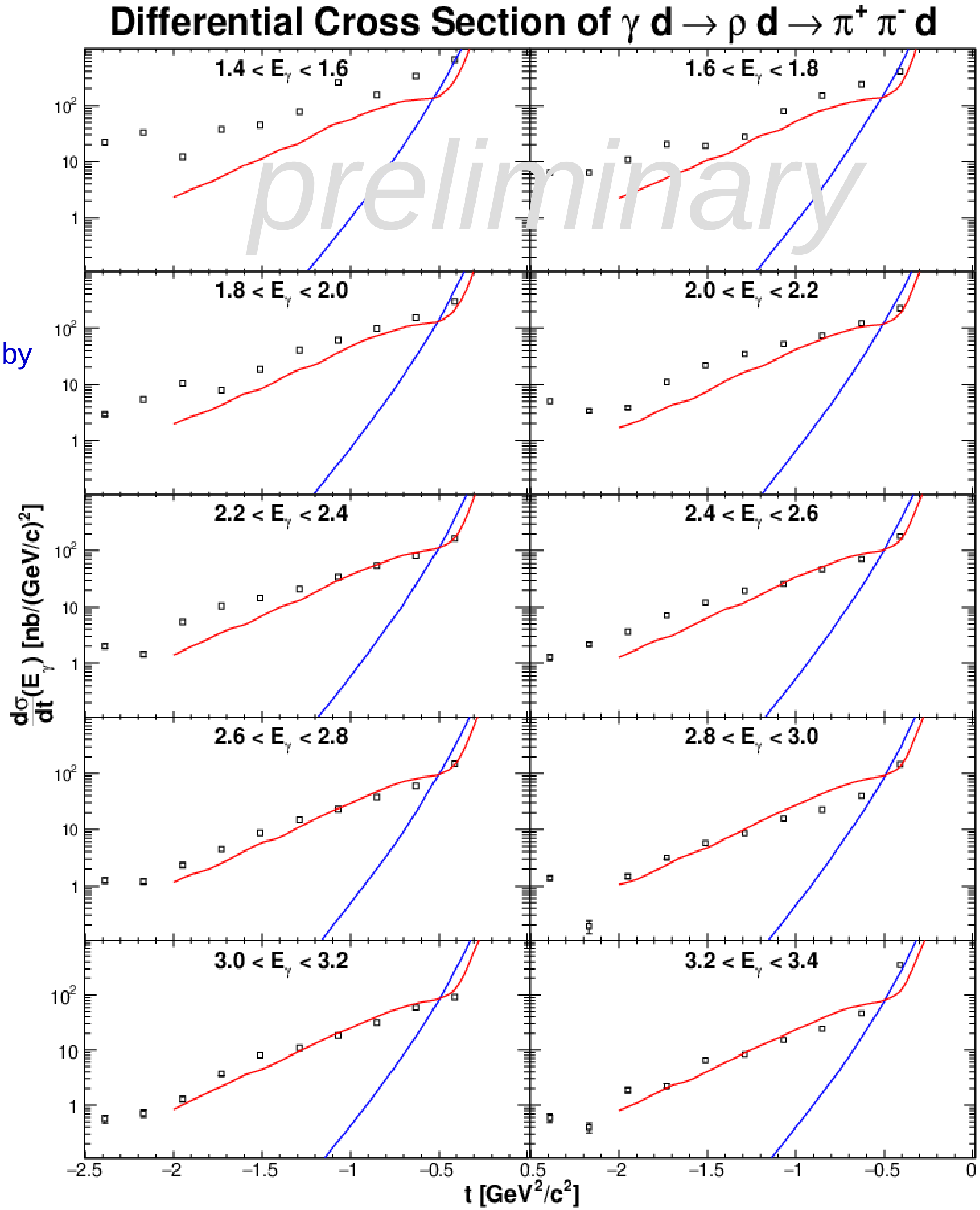
$M_d = 2.014\, g\ mole^{-1}$

$L(E_\gamma) \sim 3.8 - 1.6\, pb^{-1}$

$\delta t = 0.22\, GeV^2/c^2$

DCS

g10 results



* Calculations provided by M. Sargsian

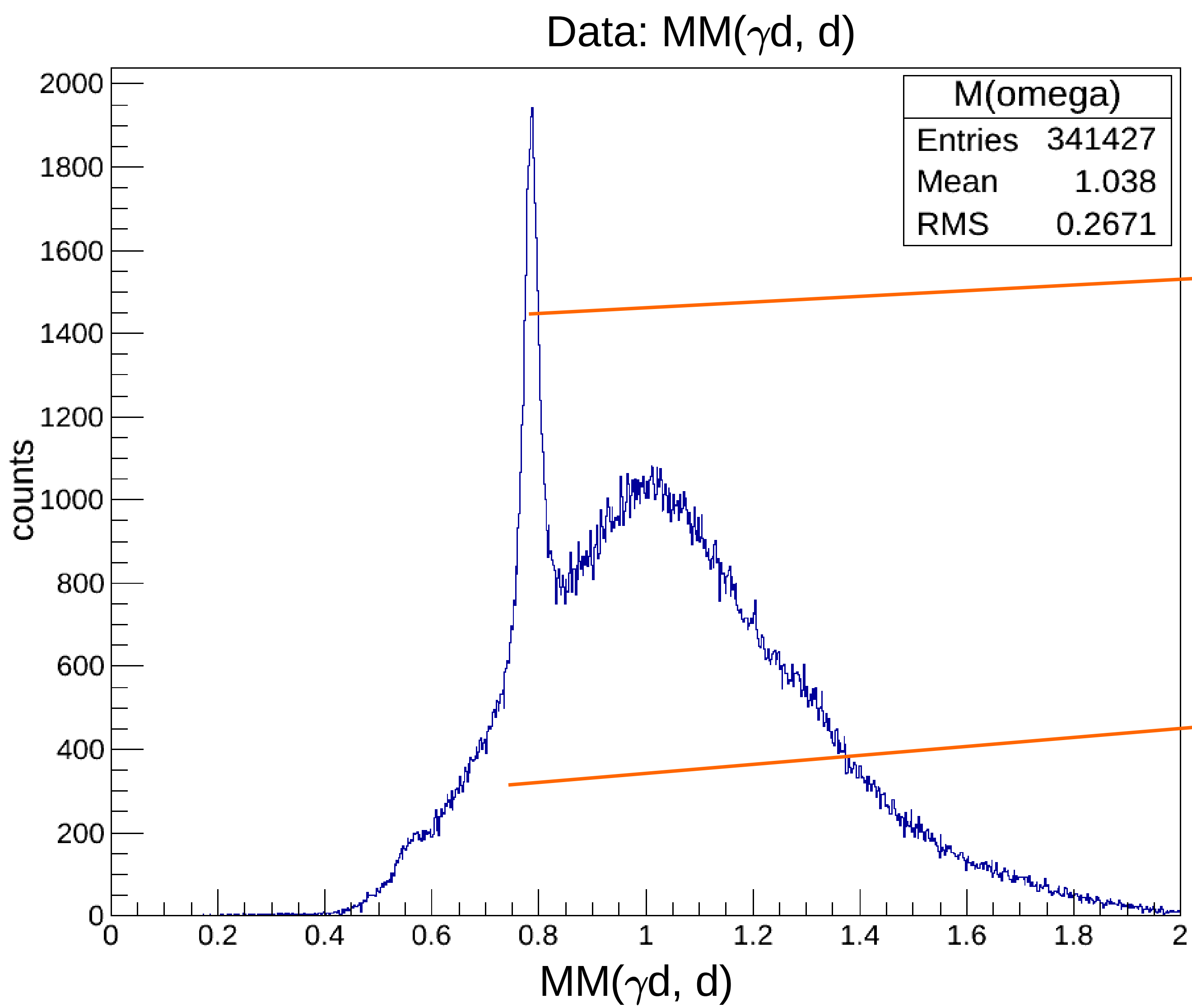
γ d → ρd → $\pi^+\pi^- d$

γ d → ωd → $\pi^+\pi^- d$ (π^0)

γ d → πd* → $\pi^+\pi^- d$

GLOBAL SPECTRUM

$\gamma\, d \rightarrow \omega d \rightarrow \pi^+\pi^- d\ (\pi^0)$



$\omega - signal$

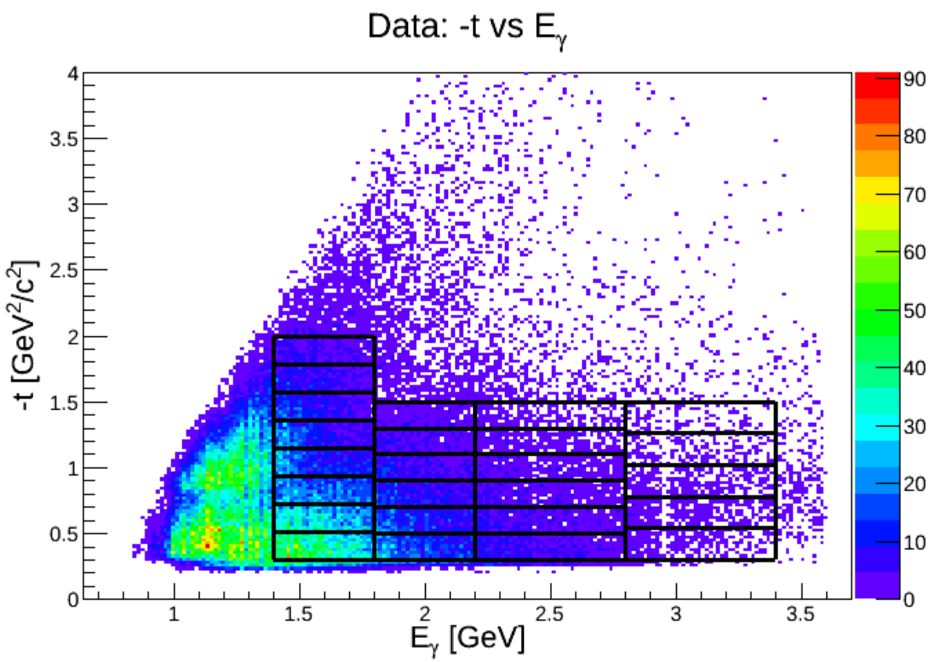
(Voigt function)

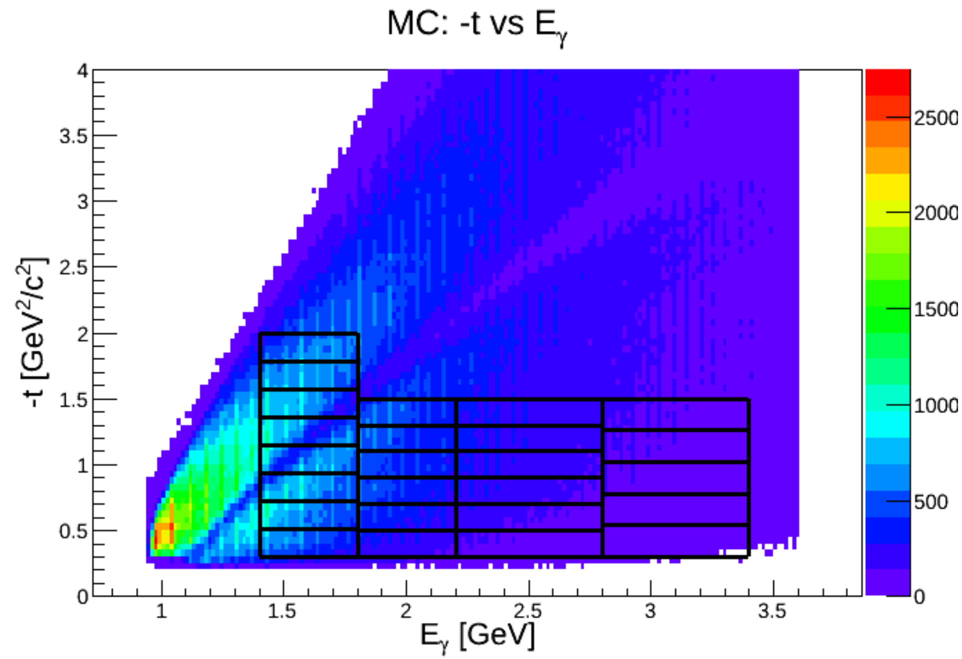
+

$f_{bckg}(x) = a + bx + cx^2 + dx^3$

background

BINNING



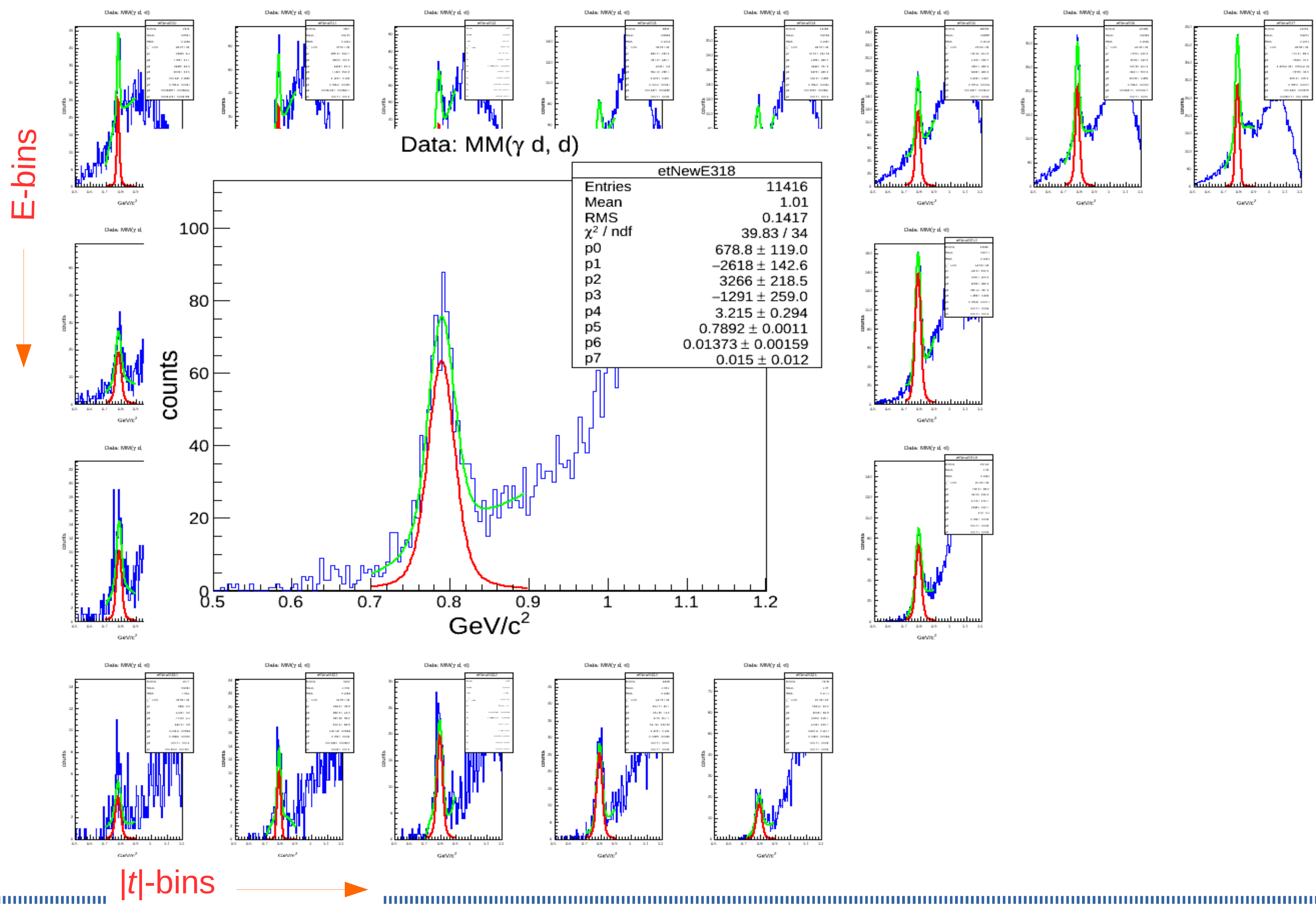


- Data and MC events binned in 5 incident photon energy and variable 4-momentum transfer bins.

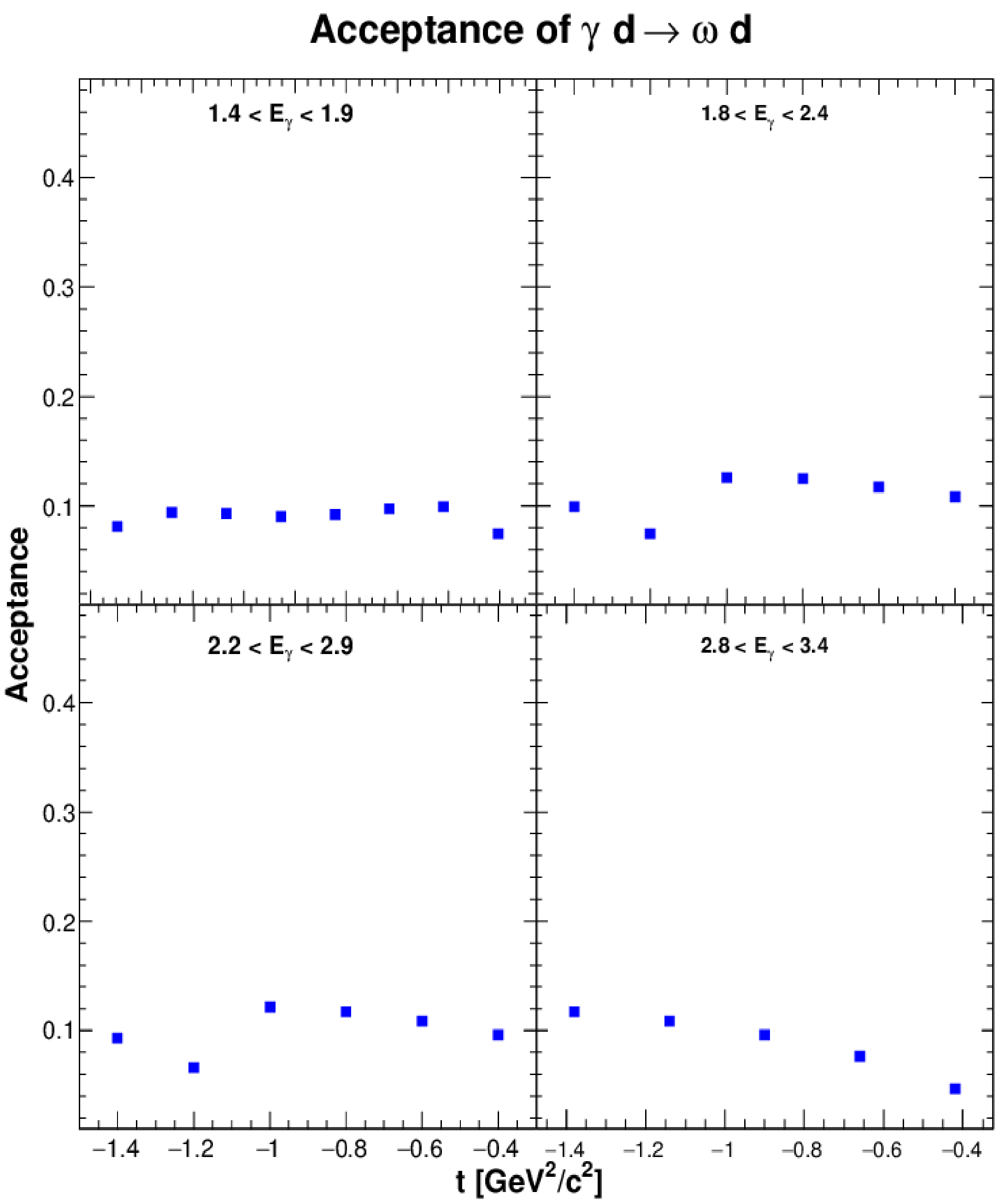
- $$1.4 < E_\gamma < 3.4\ [GeV]$$
  $$-2.5 < t_{E_{\gamma 1}} < -0.3\ [GeV^2/c^2]$$
  $$-2.0 < t_{rest} < -0.3\ [GeV^2/c^2]$$

YIELD EXTRACTION

$\gamma\, d \rightarrow \omega d \rightarrow \pi^{+}\pi^{-} d\ (\pi^{0})$



ACCEPTANCE & WORKING FORMULA



Differential Cross Section:

$$\frac{d\sigma}{dt}(E_\gamma) = \frac{Yield}{(\delta t)\, A\, L(E_\gamma)} \quad ;$$

$A \equiv Detector\ Acceptance$

Luminosity,

$$L = \frac{\rho_d N_A l_d}{M_d} N_\gamma$$

$N_\gamma \equiv N_\gamma(E_\gamma)$

$\rho_d = 0.169\, g\ cm^{-3}$

$l_d = 24\, cm$

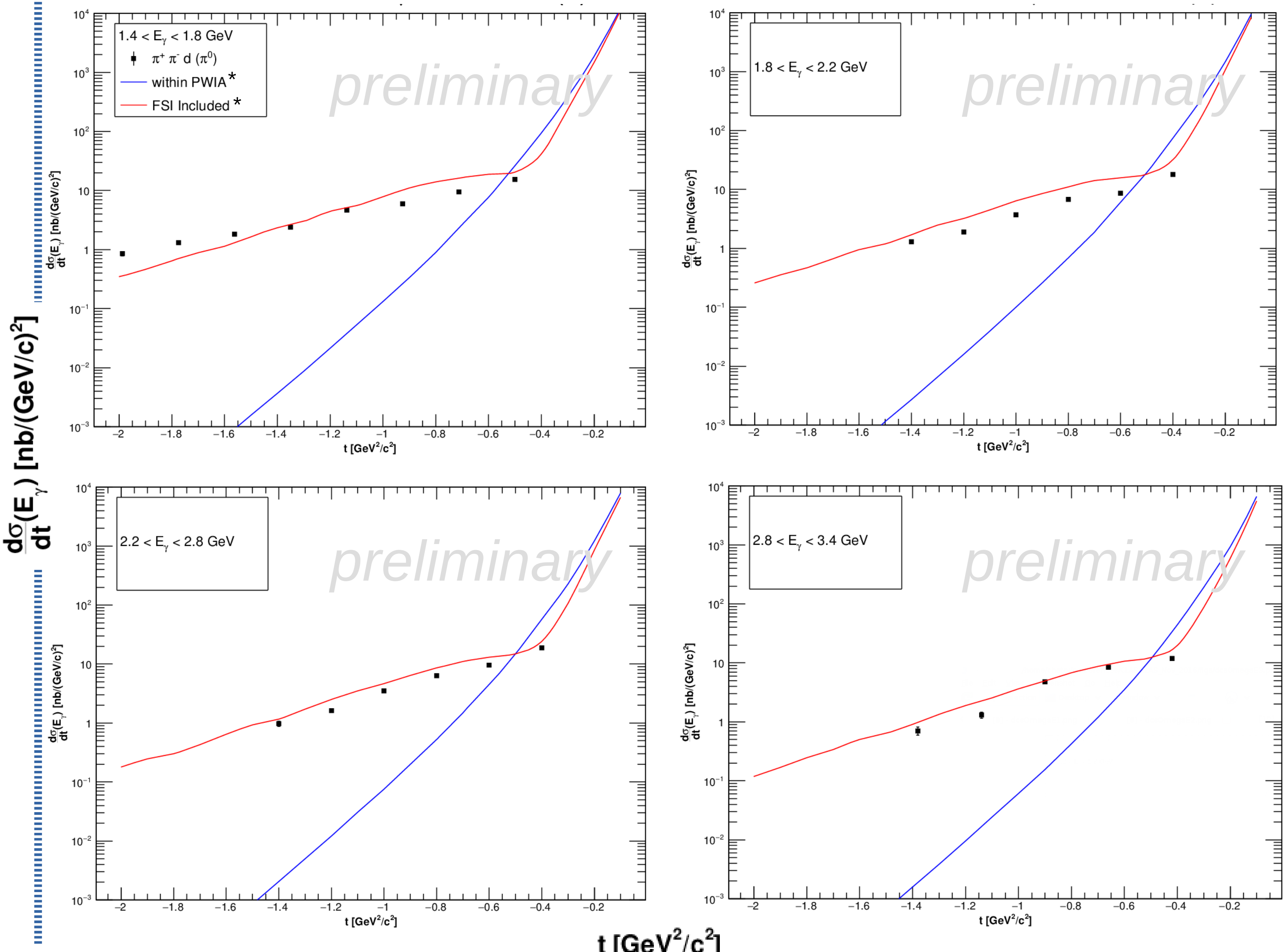
$M_d = 2.014\, g\ mole^{-1}$

$L(E_\gamma) \sim 3.8 - 1.6\, pb^{-1}$

$\delta t \equiv varies$

Differential Cross Section of $\gamma\, d \rightarrow \omega\, d \rightarrow \pi^+ \pi^- \pi^0\, d$

g10 results



DCS

* Calculations provided by M. Sargsian

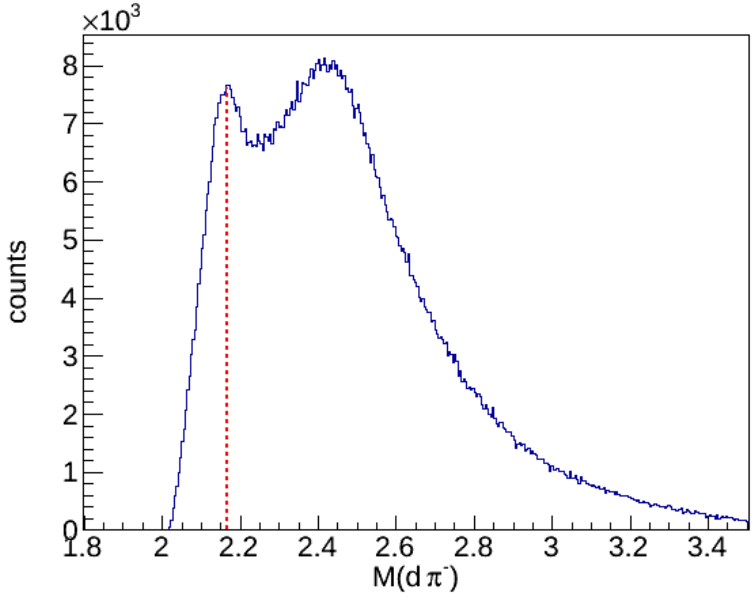
$$\gamma\, \mathrm{d} \rightarrow \rho \mathrm{d} \rightarrow \pi^{+}\pi^{-}d$$

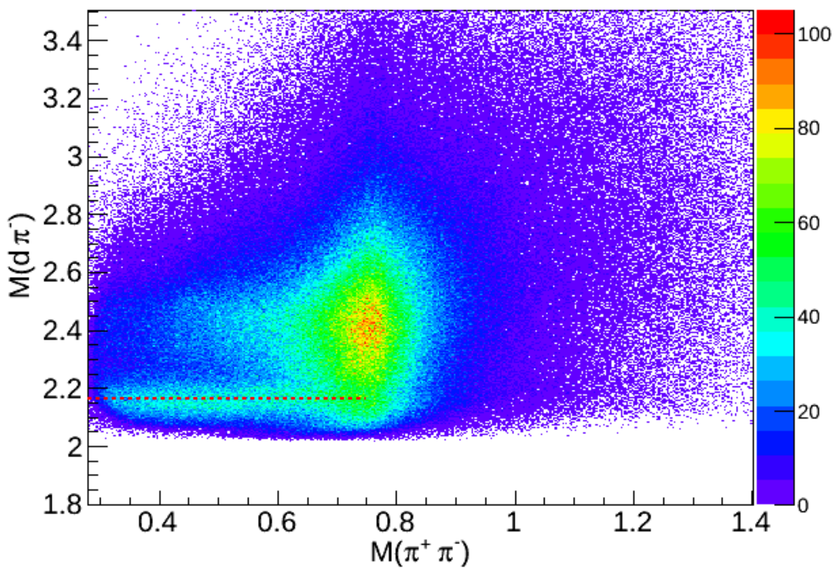
$$\gamma\, \mathrm{d} \rightarrow \omega \mathrm{d} \rightarrow \pi^{+}\pi^{-}d\ (\pi^{0})$$

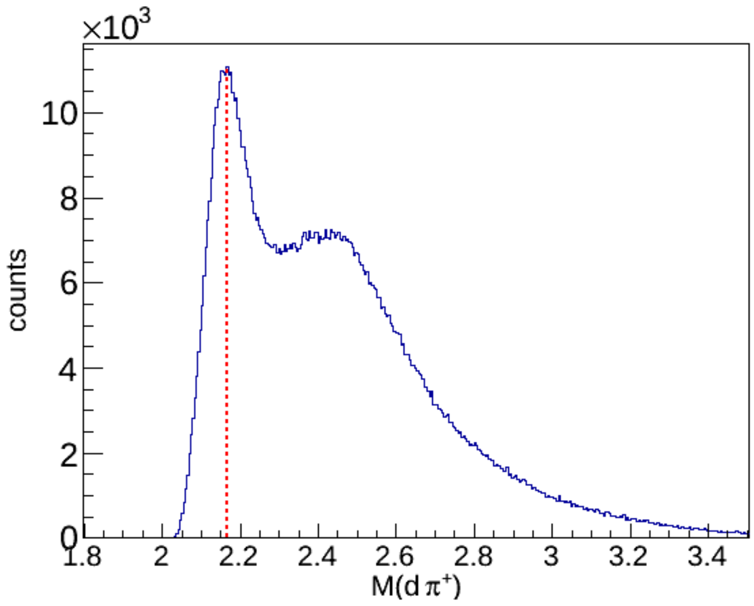
$$\gamma\, \mathrm{d} \rightarrow \pi \mathrm{d}^{*} \rightarrow \pi^{+}\pi^{-}d$$

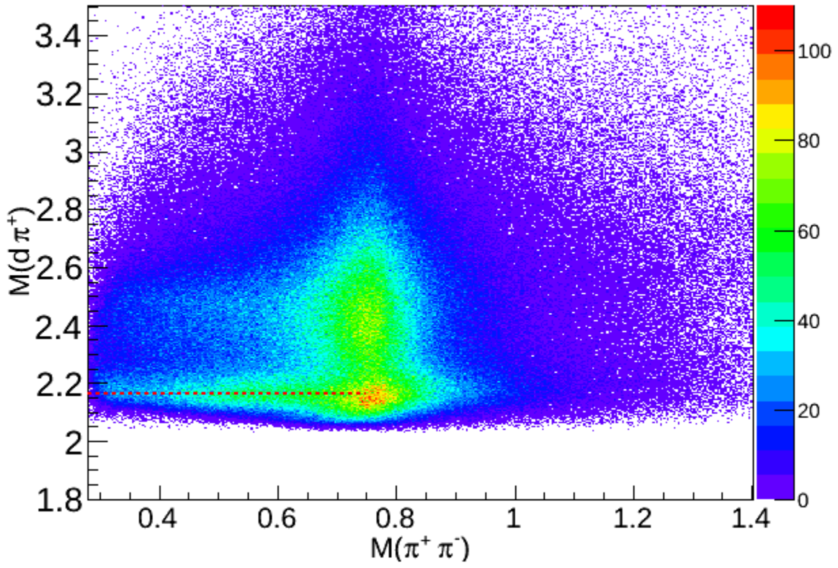
WHAT WE SEE

$\gamma\, d \rightarrow \pi d^* \rightarrow \pi^+\pi^- d$



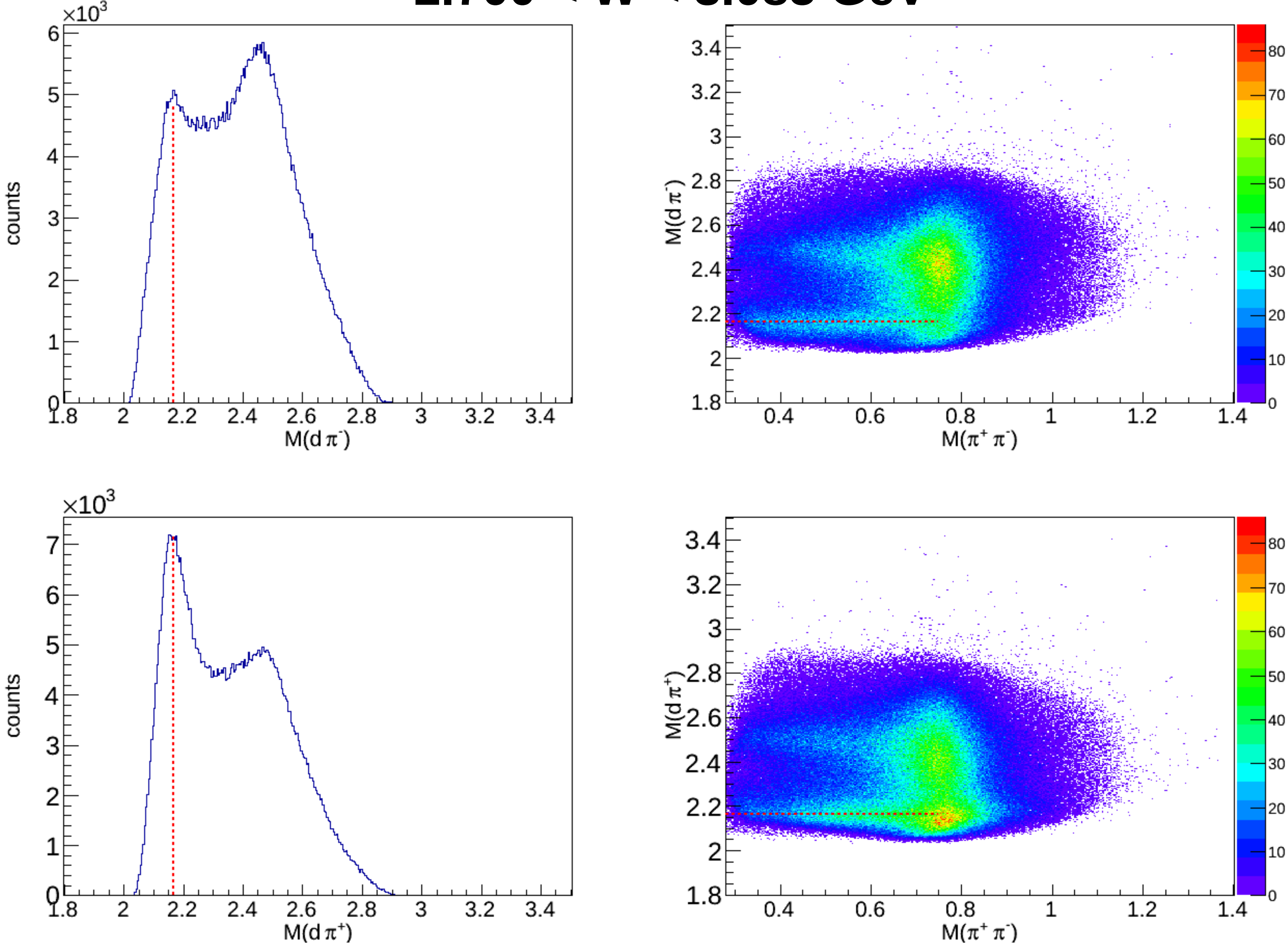




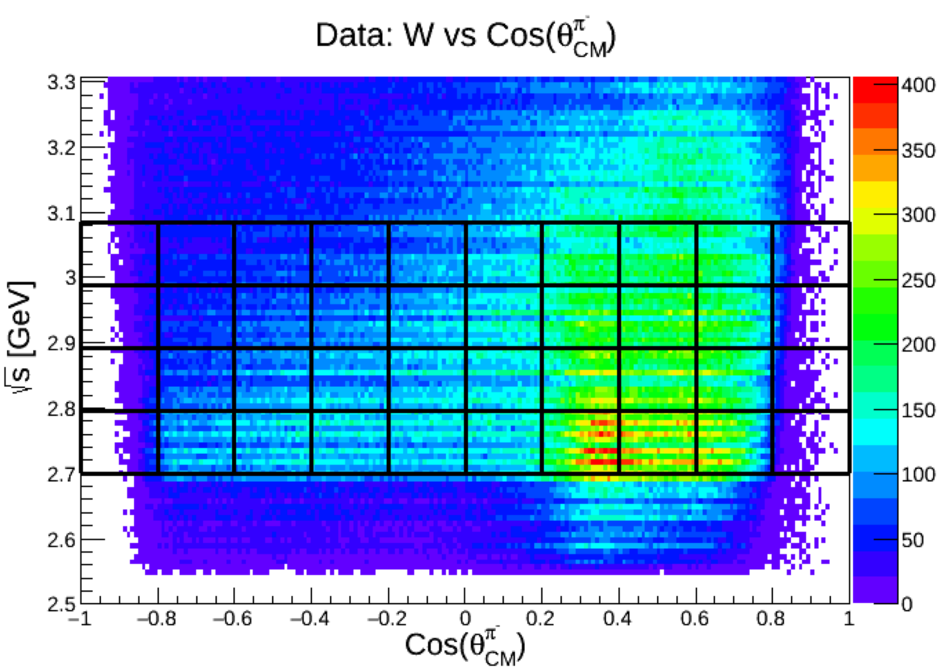


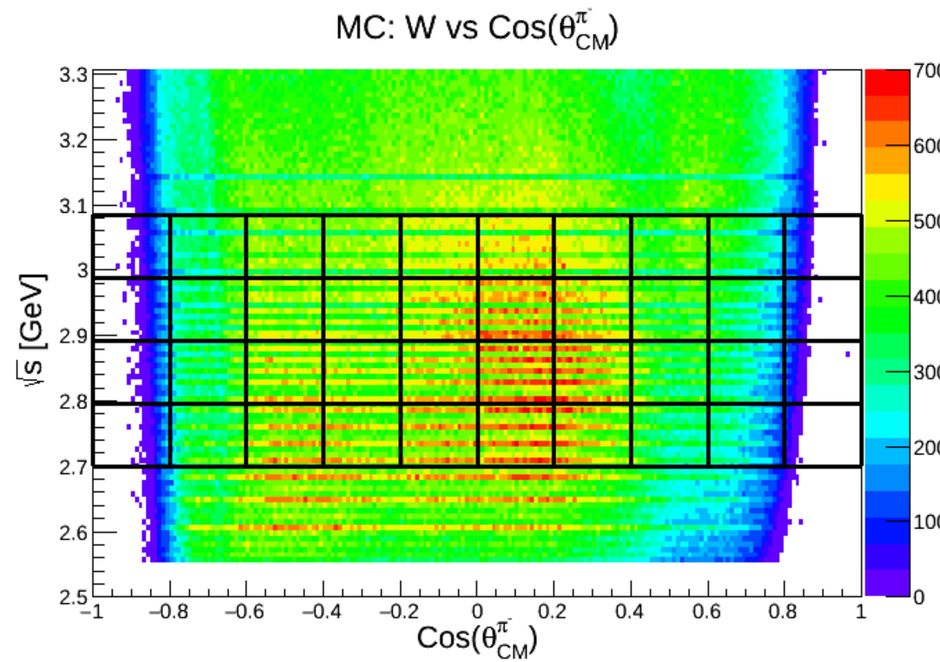
WHAT WE SEE

2.700 < W < 3.085 GeV



BINNING

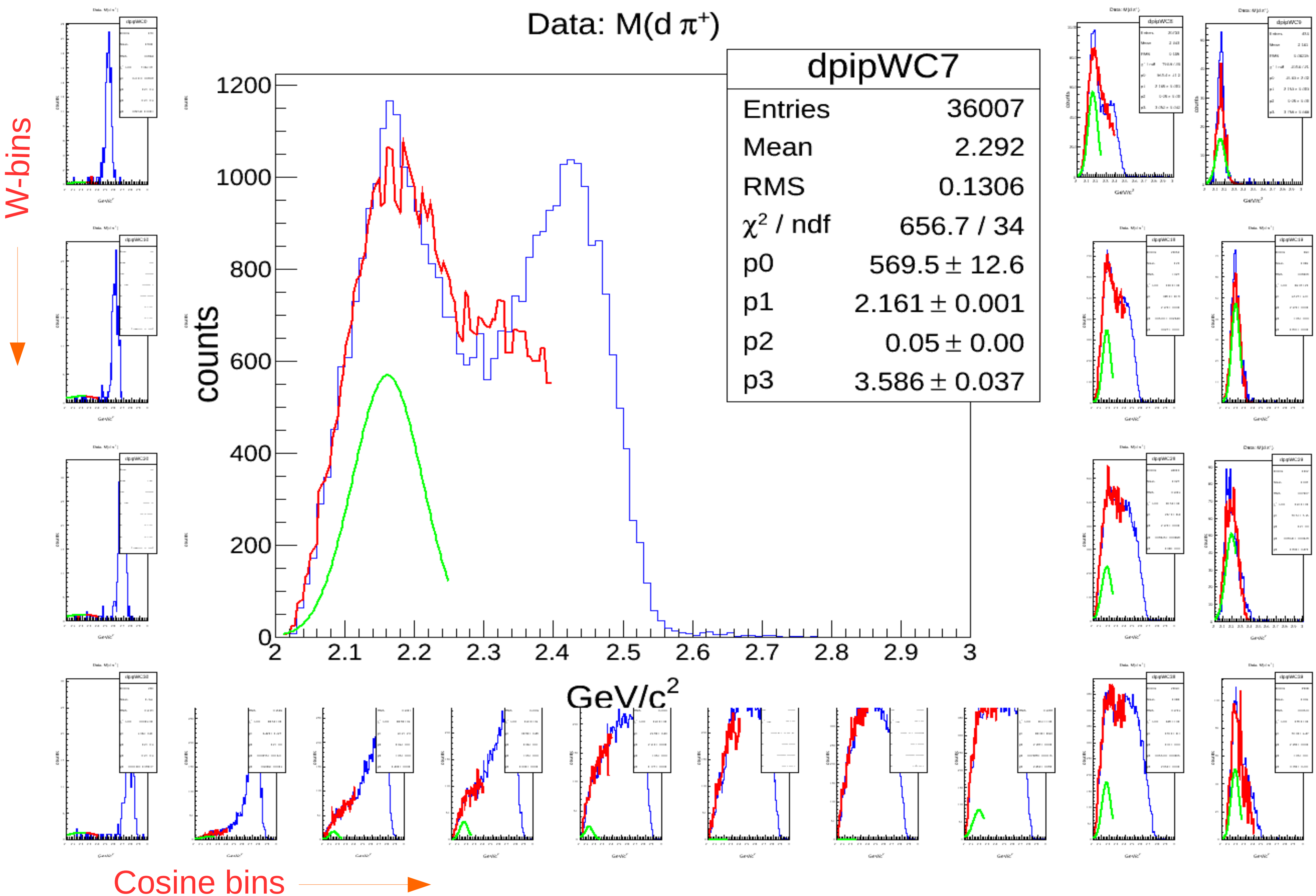




- Data and MC events binned in 4 W bins and 10 angle bins.
- $1.4 < E_\gamma < 1.6 \;[GeV]$
  $2.70 < W < 3.085 \;[GeV]$
  $-1.0 < \cos\left(\theta_{CM}^{\pi^+}\right) < 1.0$

YIELD EXTRACTION

$\gamma\, d \rightarrow \pi d^* \rightarrow \pi^+ \pi^- d$



DIFFERENTIAL CROSS SECTION (DCS)

Working formula for DCS:

$$\frac{d\sigma}{d\cos(\theta_{CM}^{\pi})}(W)=\frac{Yield}{\delta(\cos(\theta_{CM}^{\pi}))\,A\,L(W)}$$

$A \equiv Detector\ Acceptance$

Luminosity,

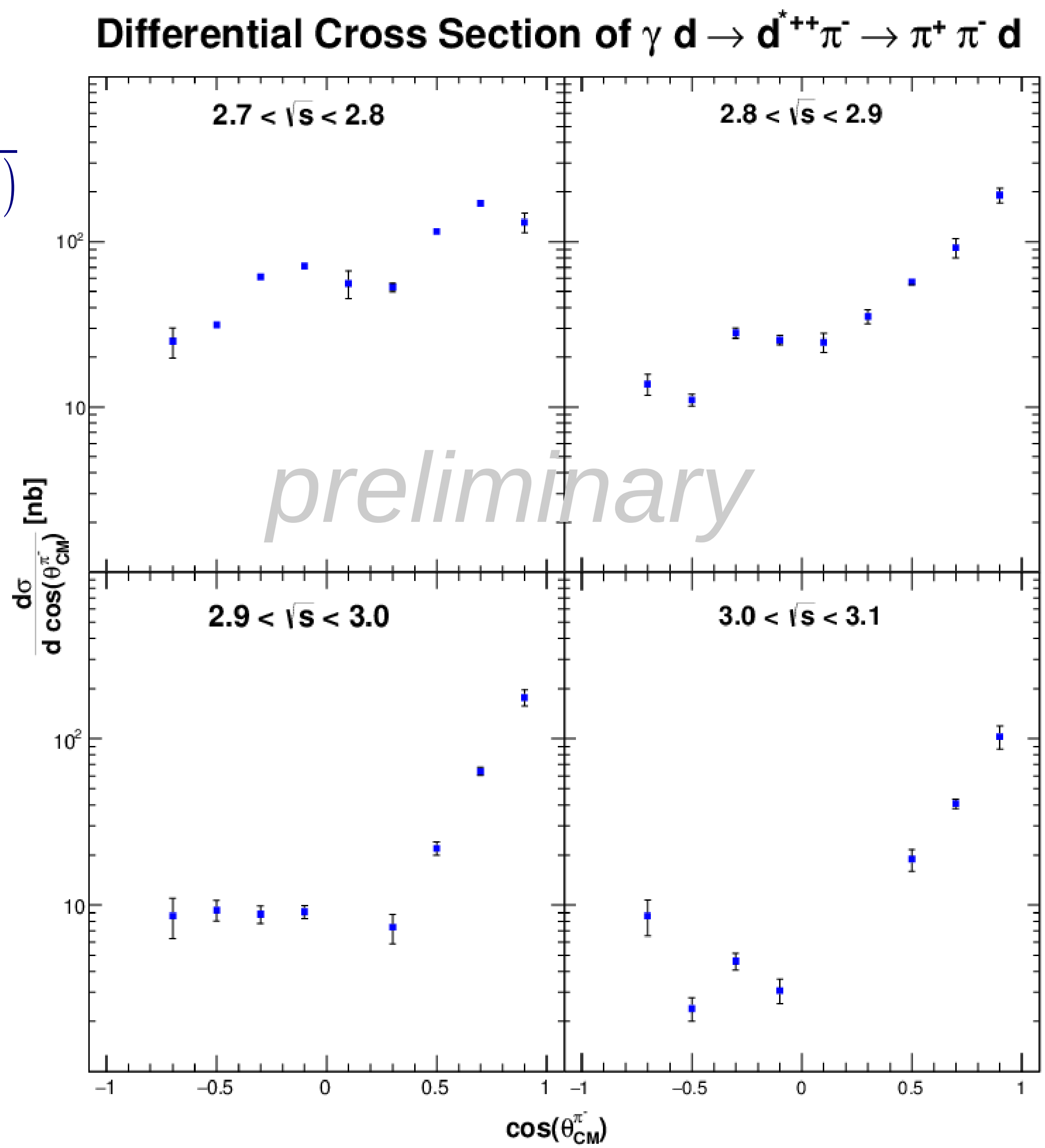
$$L=\frac{\rho_d N_A l_d}{M_d} N_\gamma$$

$N_\gamma \equiv N_\gamma(W)$

$\rho_d = 0.169\ g\ cm^{-3}$
$l_d = 24\ cm$
$M_d = 2.014\ g\ mole^{-1}$

$L(W) \sim 3.0 - 2.3\ pb^{-1}$

$\delta\cos(\theta_{CM}^{\pi}) = 0.2$



CONCLUSION

- The vector meson cross-section data provides sensitivity to the nucleon-scattering data for higher |*t*|-values.
- DCS for vector meson channels verify diffractive scattering processes as expected.
- Understanding this reaction channel will help understand its interference in the d* resonance
    - γ d → πd* → $\pi^+\pi^- d$
- Forward peaking differential cross section for the d^{*++}
- Next steps would include:
    - Study of |*t*|-slope dependence in MC for vector meson channels.
    - Study of systematic uncertainties
    - Comparison with theory including interference effects

Extras!!

INVESTIGATED CHANNELS

Extras!

$$\gamma d \rightarrow \rho d \rightarrow \pi^{+} \pi^{-} d$$

$\rho(770)$ [h] $I^G(J^{PC}) = 1^+(1^{--})$

Mass $m = 775.26 \pm 0.25$ MeV
Full width $\Gamma = 149.1 \pm 0.8$ MeV
$\Gamma_{ee} = 7.04 \pm 0.06$ keV

$\rho(770)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
$\pi\pi$	$\sim$ 100 %		363

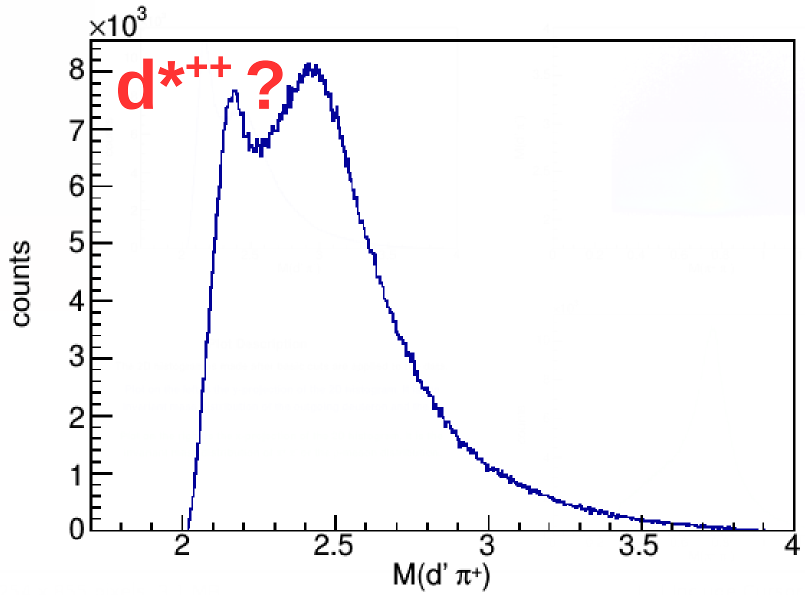
$$\gamma d \rightarrow \omega d \rightarrow \pi^{+} \pi^{-} d \left(\pi^{0}\right)$$

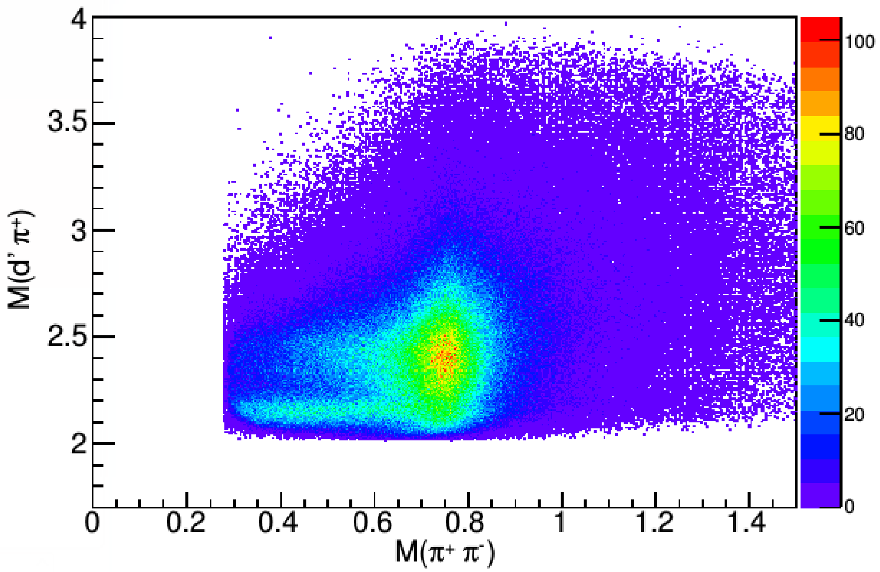
$\omega(782)$ $I^G(J^{PC}) = 0^-(1^{--})$

Mass $m = 782.65 \pm 0.12$ MeV (S = 1.9)
Full width $\Gamma = 8.49 \pm 0.08$ MeV
$\Gamma_{ee} = 0.60 \pm 0.02$ keV

$\omega(782)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
$\pi^+\pi^-\pi^0$	(89.2 ± 0.7) %		327
$\pi^0\gamma$	(8.28 ± 0.28) %	S=2.1	380
$\pi^+\pi^-$	$(1.53^{+0.11}_{-0.13})$ %	S=1.2	366

INTERFERENCE



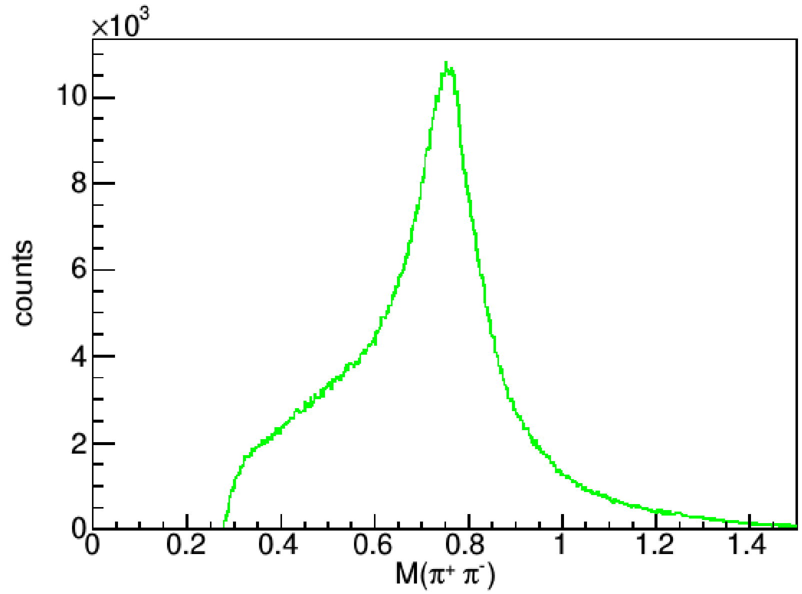


Plot Description

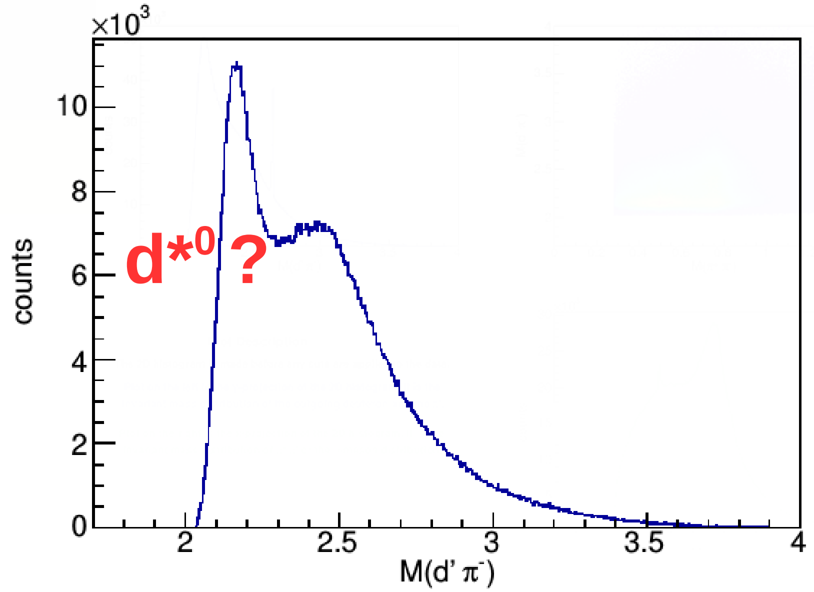
The 2D histogram is made after basic cuts are applied to the data.

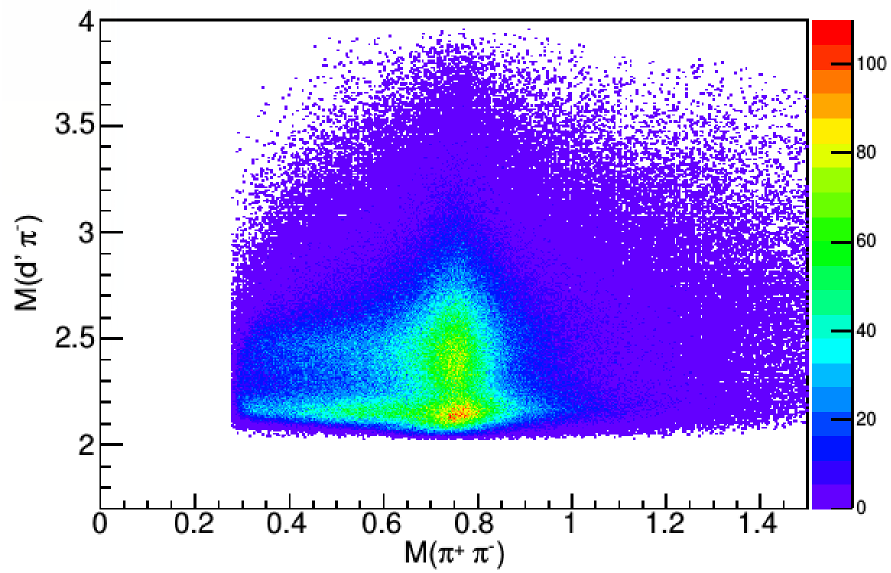
Plot on the left is the y-projection of the 2D histogram. It is the invariant mass distribution of the outgoing deuteron and the π^+.

Plot on the right is the x-projection of the 2D histogram. It is the invariant mass distribution of $\pi^+ \pi^-$ or the ρ-meson distribution.



INTERFERENCE



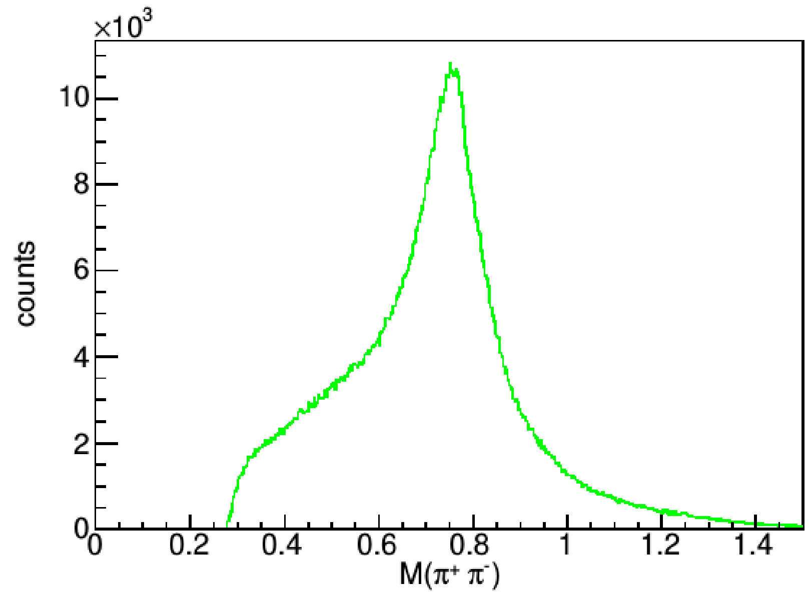


Plot Description

The 2D histogram is made after basic cuts are applied to the data.

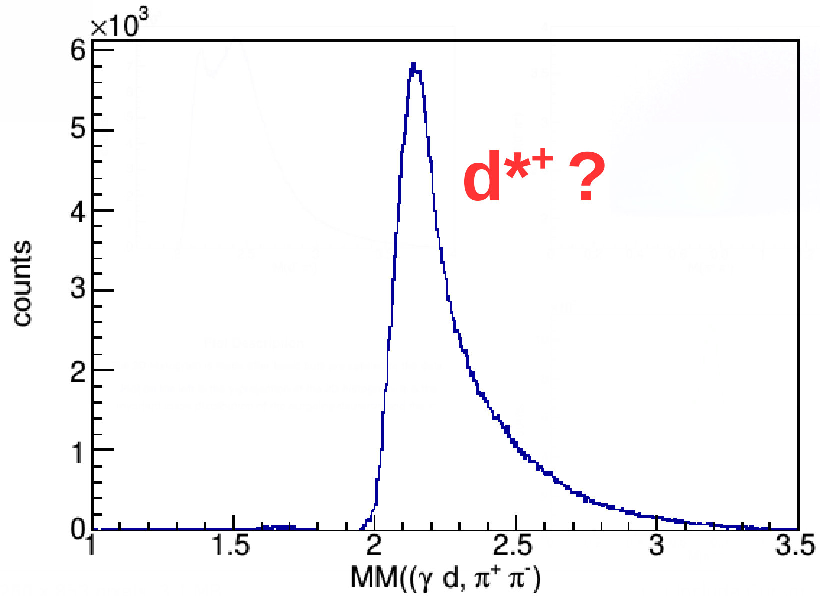
Plot on the left is the y-projection of the 2D histogram. It is the invariant mass distribution of the outgoing deuteron and the π^-.

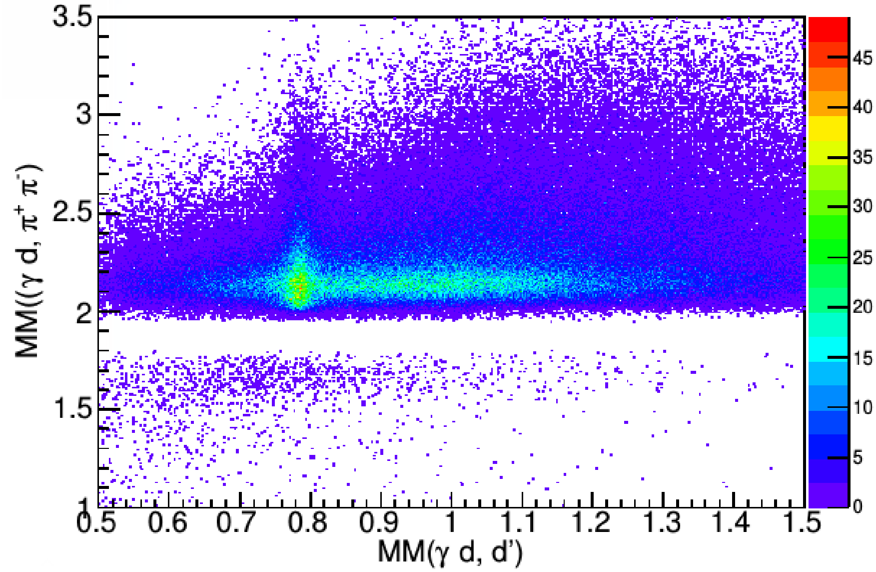
Plot on the right is the x-projection of the 2D histogram. It is the invariant mass distribution of $\pi^+ \pi^-$ or the ρ-meson distribution.



INTERFERENCE

Extras!





Plot Description

The 2D histogram is made after basic cuts are applied to the data.

Plot on the left is the y-projection of the 2D histogram. It is the mass distribution for the π^0 and the outgoing d.

Plot on the right is the x-projection of the 2D histogram. It is the mass distribution for $\pi^+ \pi^- \pi^0$ or the ω-meson distribution.